

# The effects of normal metal stripes on TES performance.

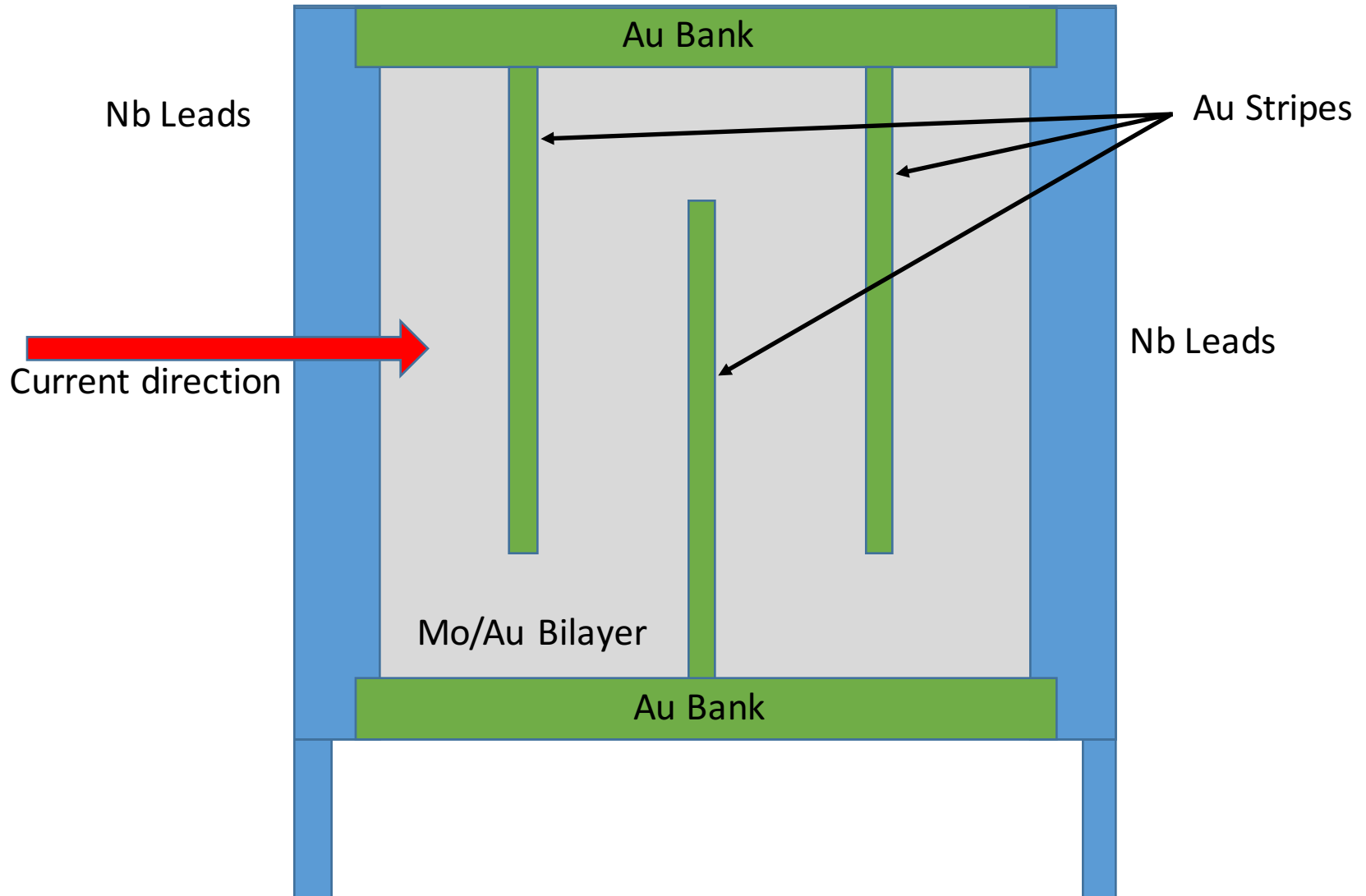
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J.S. Adams, S.R. Bandler, J.A. Chervenak, A.M. Datesman, M.E. Eckart, F. M. Finkbeiner, R.L. Kelley, , C.A. Kilbourne, A.R. Miniussi, F.S. Porter, J.S. Sadleir, K. Sakai, S.J. Smith, E.J. Wassell, W. Yoon.

# Typical TES design

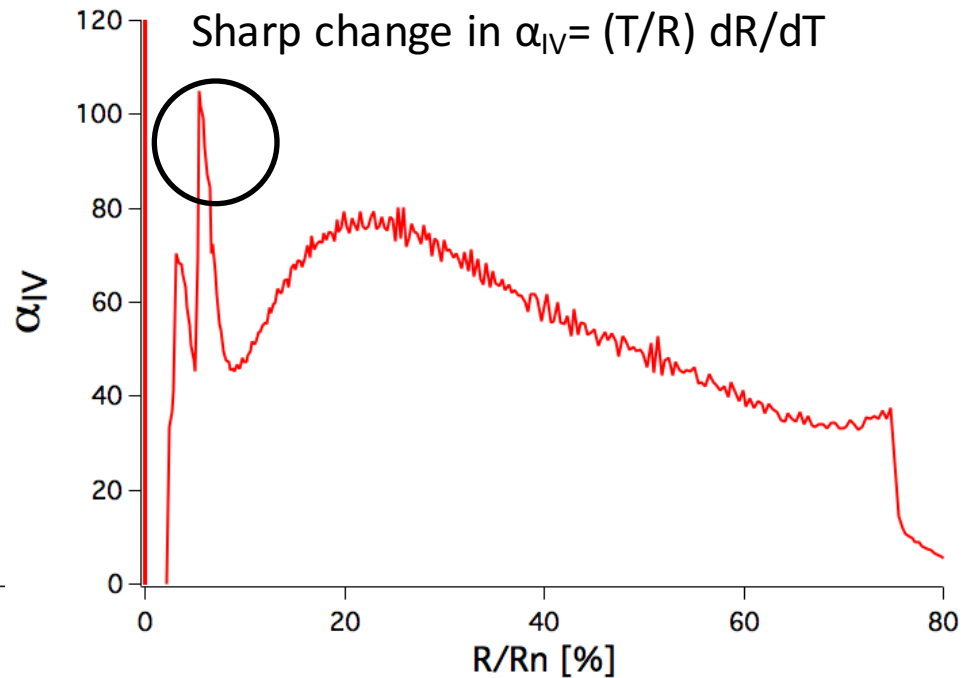
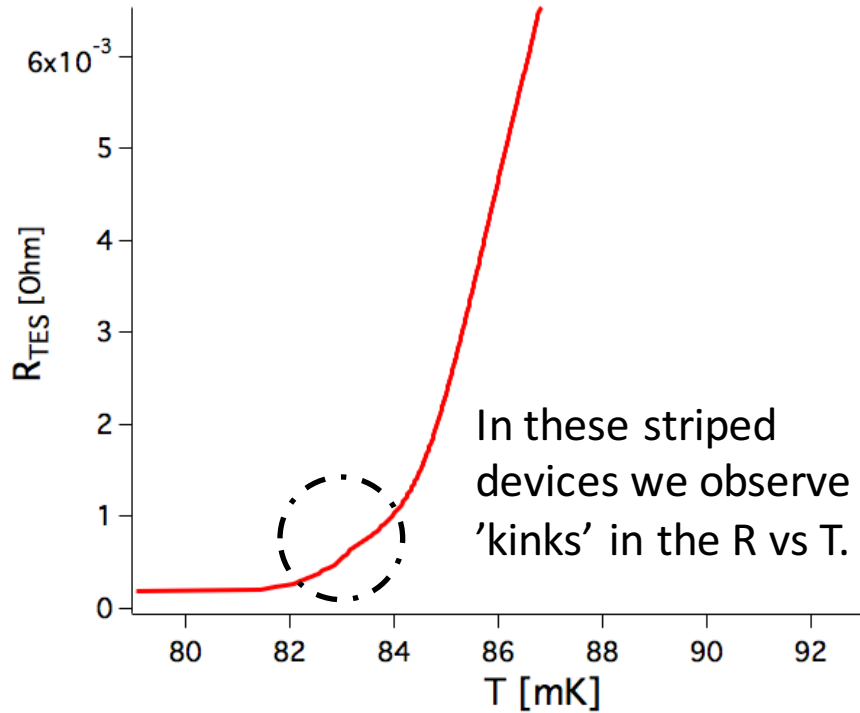
Au stripes perpendicular to current direction reduce the magnitude of the unexplained (excess) contribution to electrical noise of TES.



# Kinks in the transition

Measure an I-V curve for TES at  $T_{\text{bath}} = 55\text{mK}$ .

Use this to deduce  $R(T)$  from knowledge of thermal conductance



Close to these regions we observe very large unexplained noise and poor spectral performance.

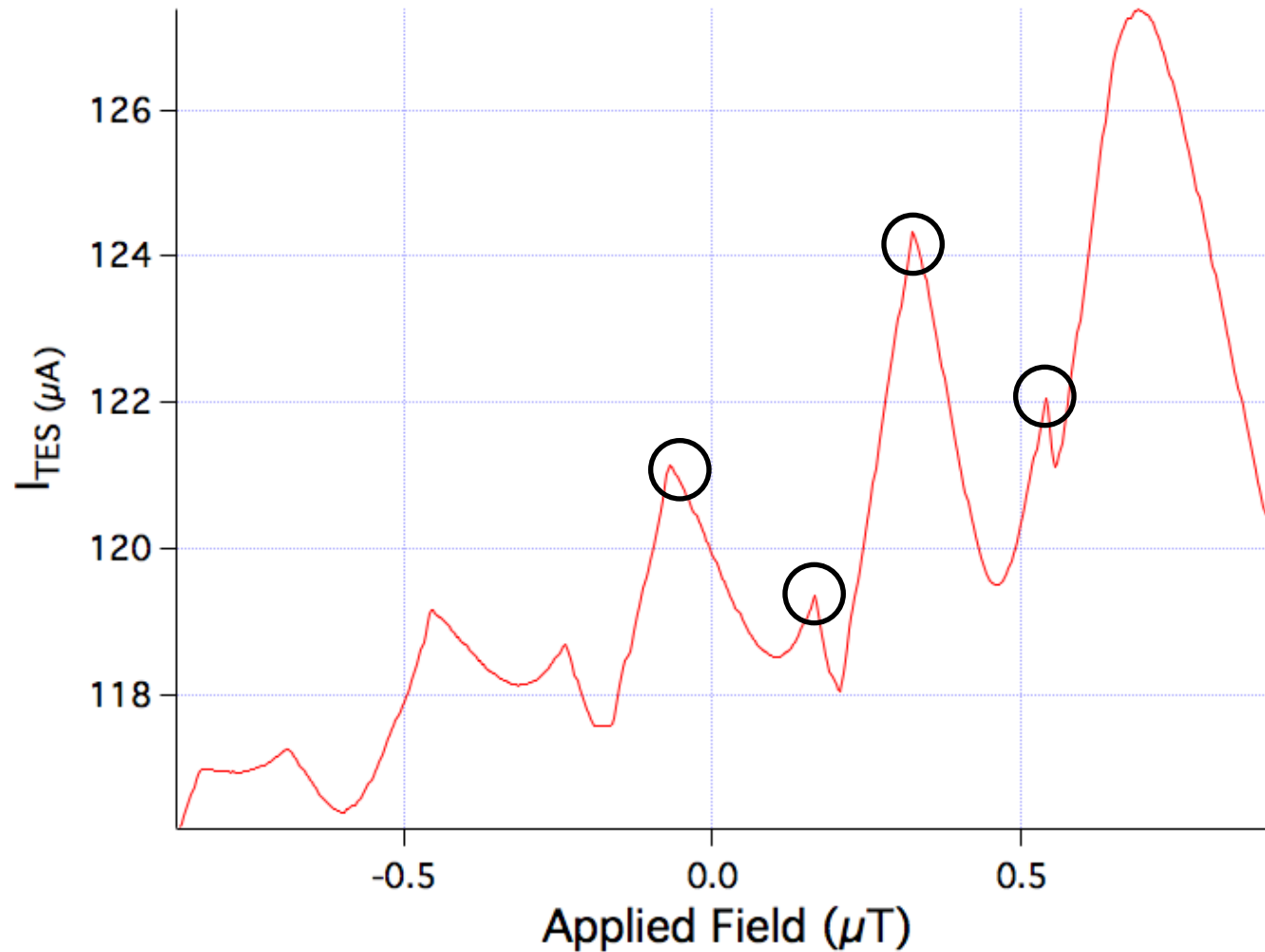
Typically we bias the TES away from these regions and can still obtain good performance.

But position of kink is sensitively dependent on thermal conductance,  $T_c$  and magnetic field.

Therefore optimizing this on the array scale can be very challenging

$$I_{\text{TES}}(B)$$

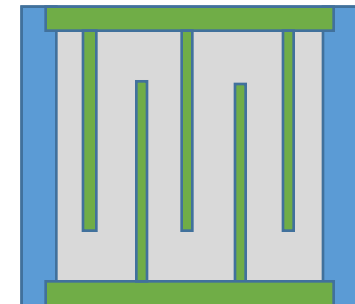
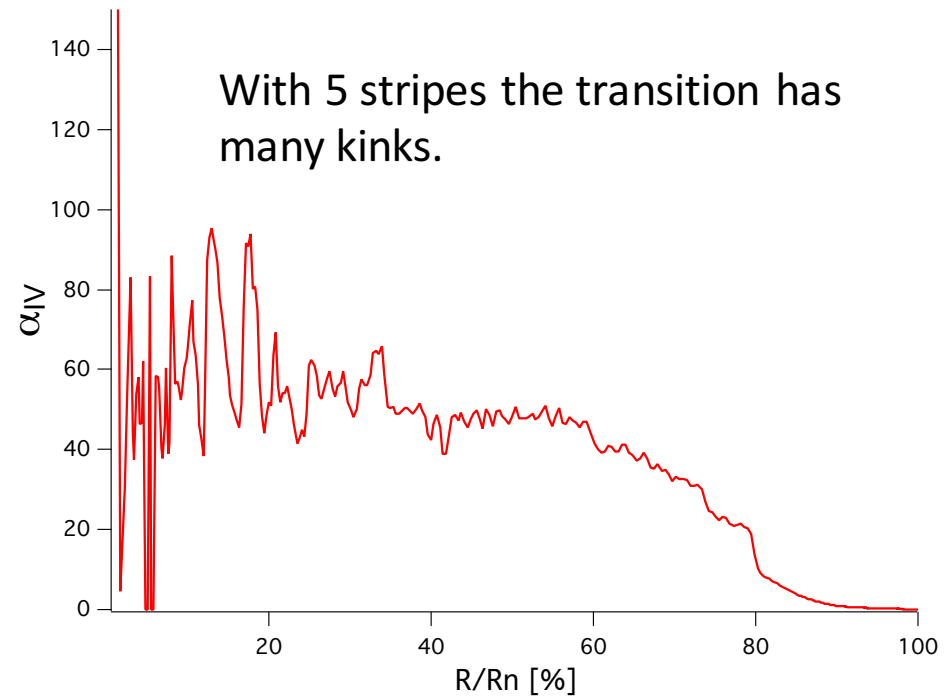
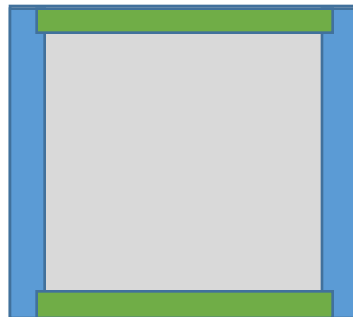
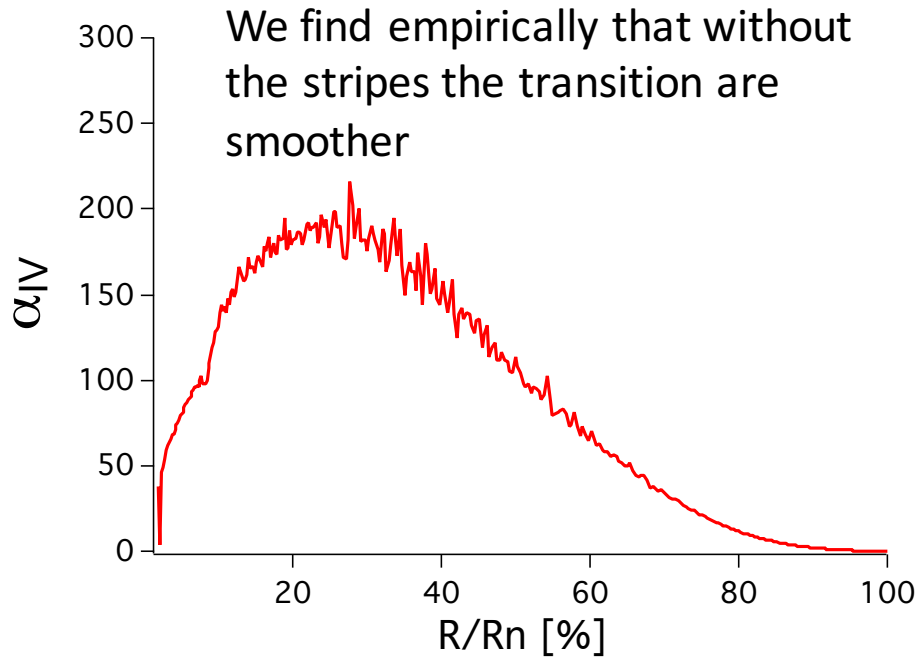
The kinks can also be identified from changes in slope of the current through the TES at constant bias voltage as a function of field:  $I_{\text{TES}}(B)$



$R/R_n \sim 5\%$   
 $T_{\text{bath}} = 55\text{mK}$

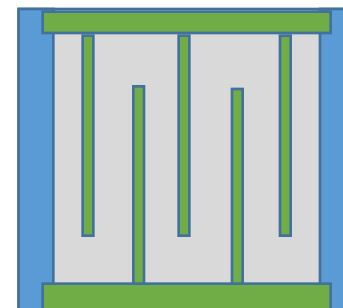
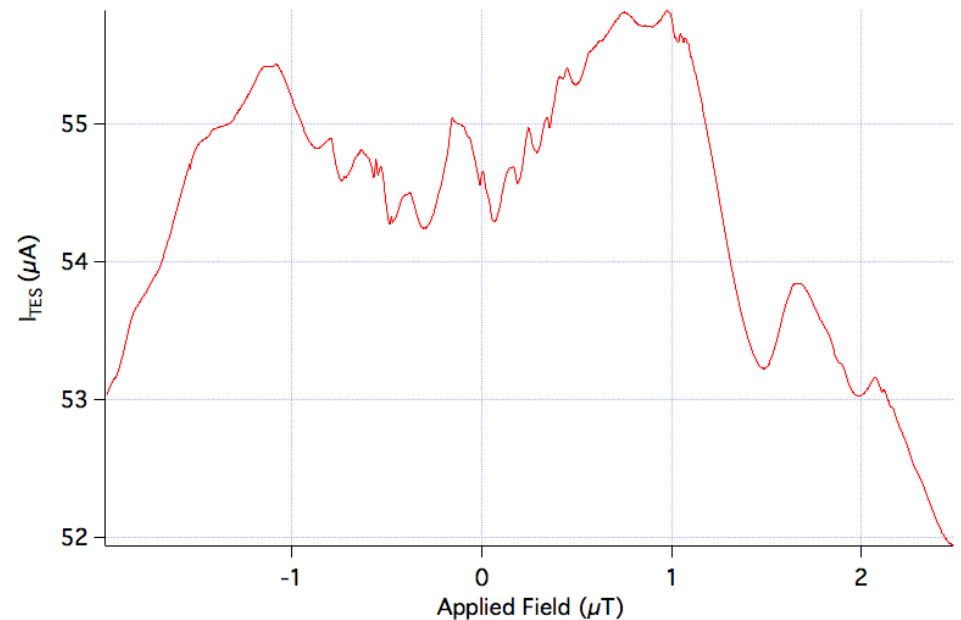
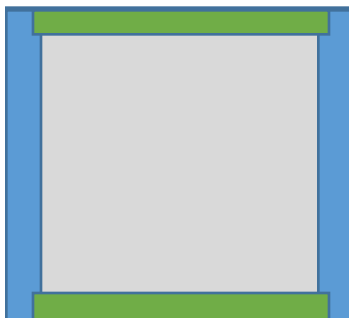
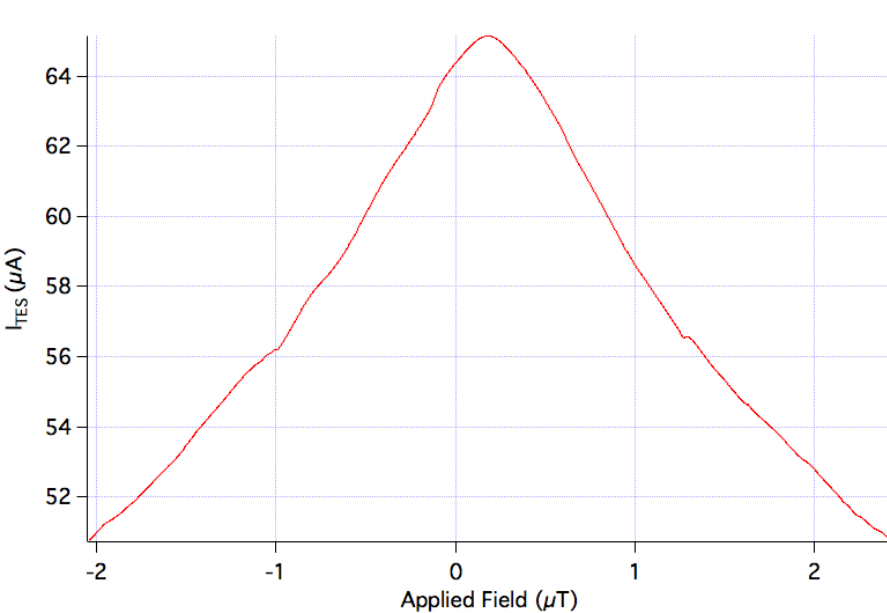
# The effect of stripes on $\alpha_V$ in 140 $\mu\text{m}$ TES

We have taken measurements of devices with different stripe patterns on a single chip.



# The effect of stripes on $I_{\text{TES}}(B)$

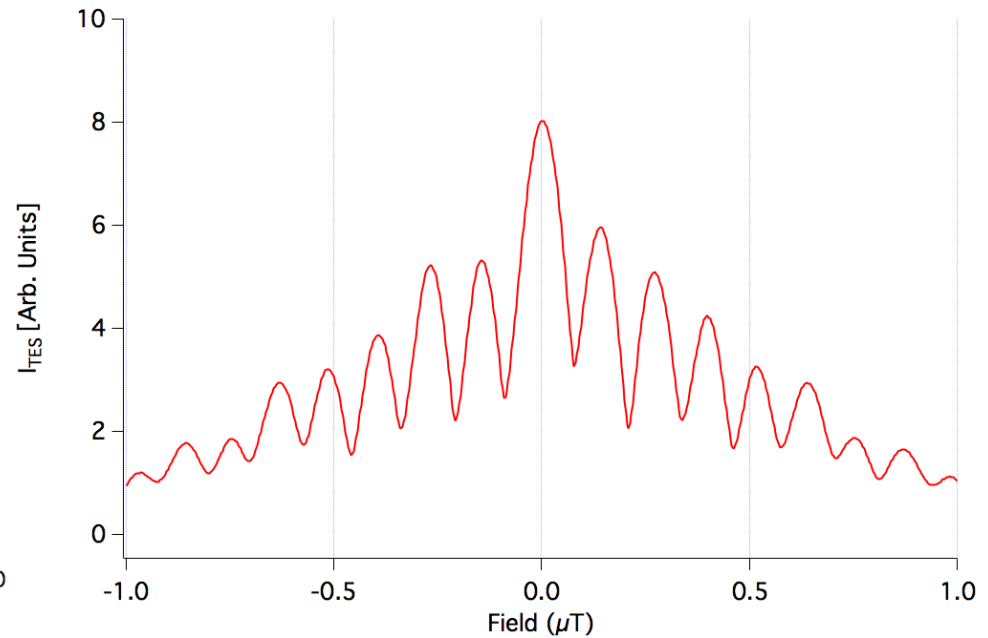
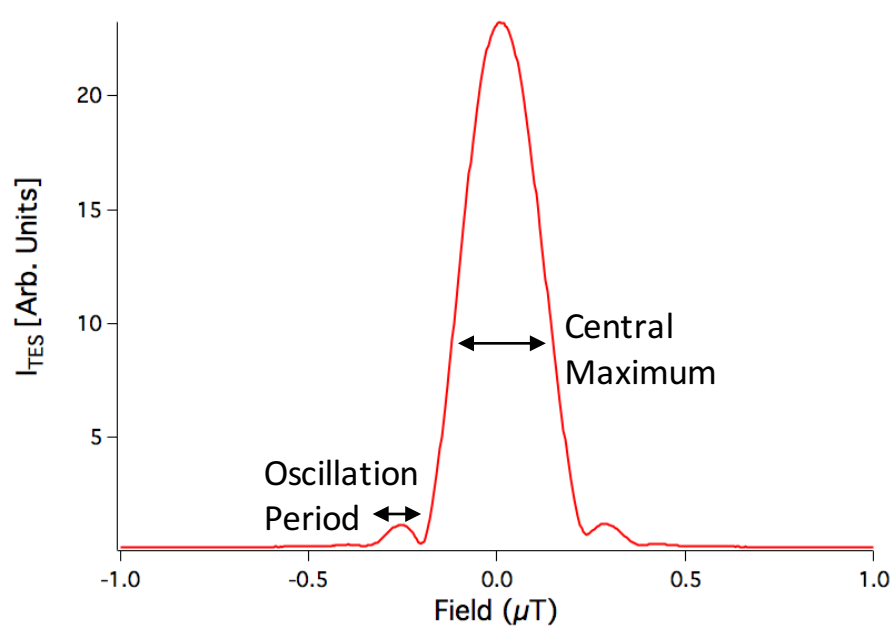
$R/R_n \sim 3\%$   
 $T_{\text{bath}} = 55\text{mK}$



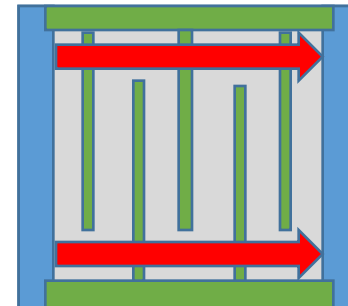
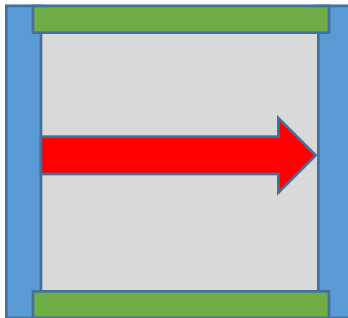
# $I_{\text{TES}}(B)$ close to $T_c$

When  $T_{\text{bath}} \simeq T_c$ ,  $I_{\text{TES}} \simeq I_c$

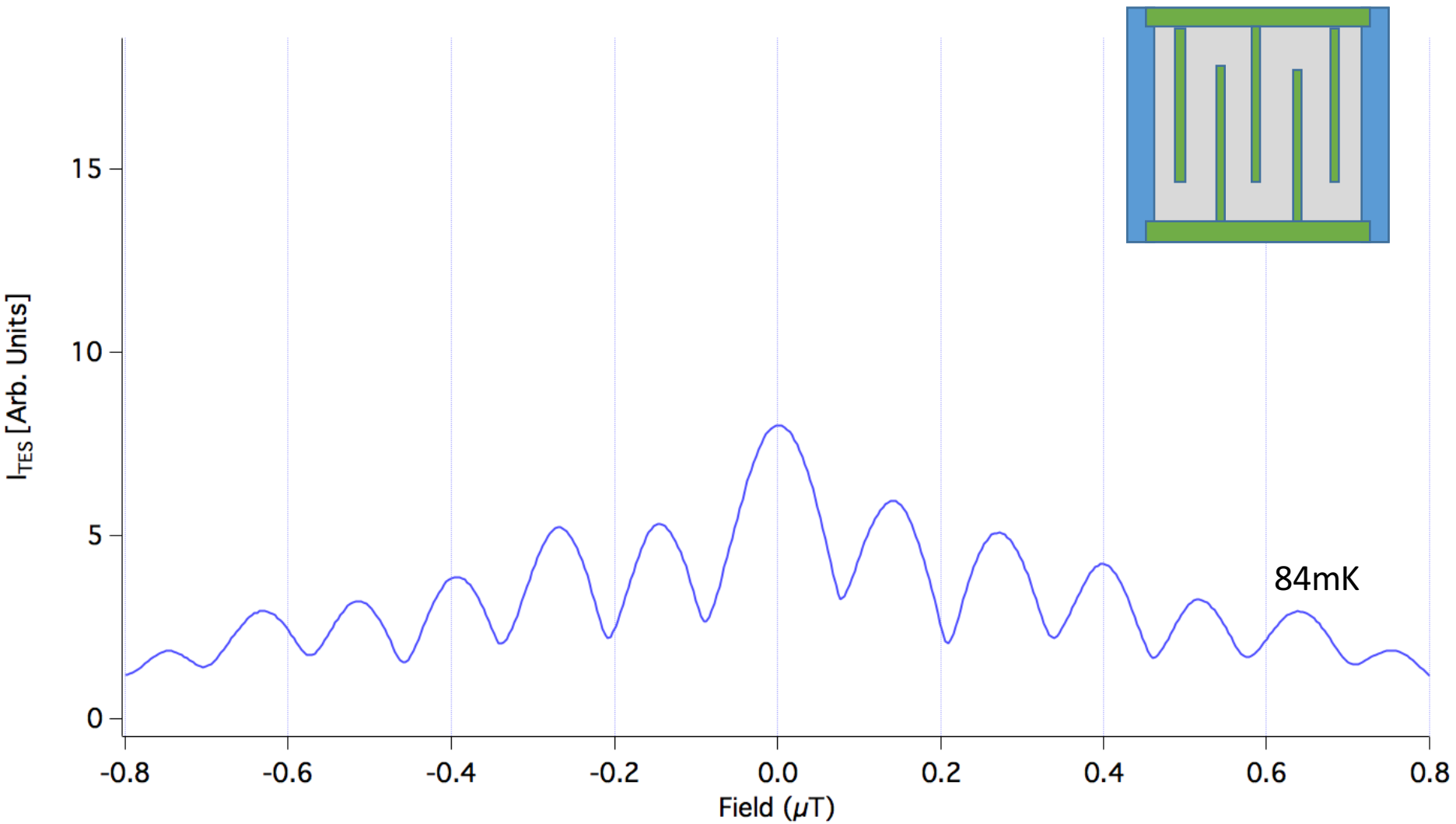
Fraunhofer-type pattern ---- TES acts as a weak-link Josephson junction  
Oscillation period equal, central maximum very different.



This implies a very different current distribution in the two cases



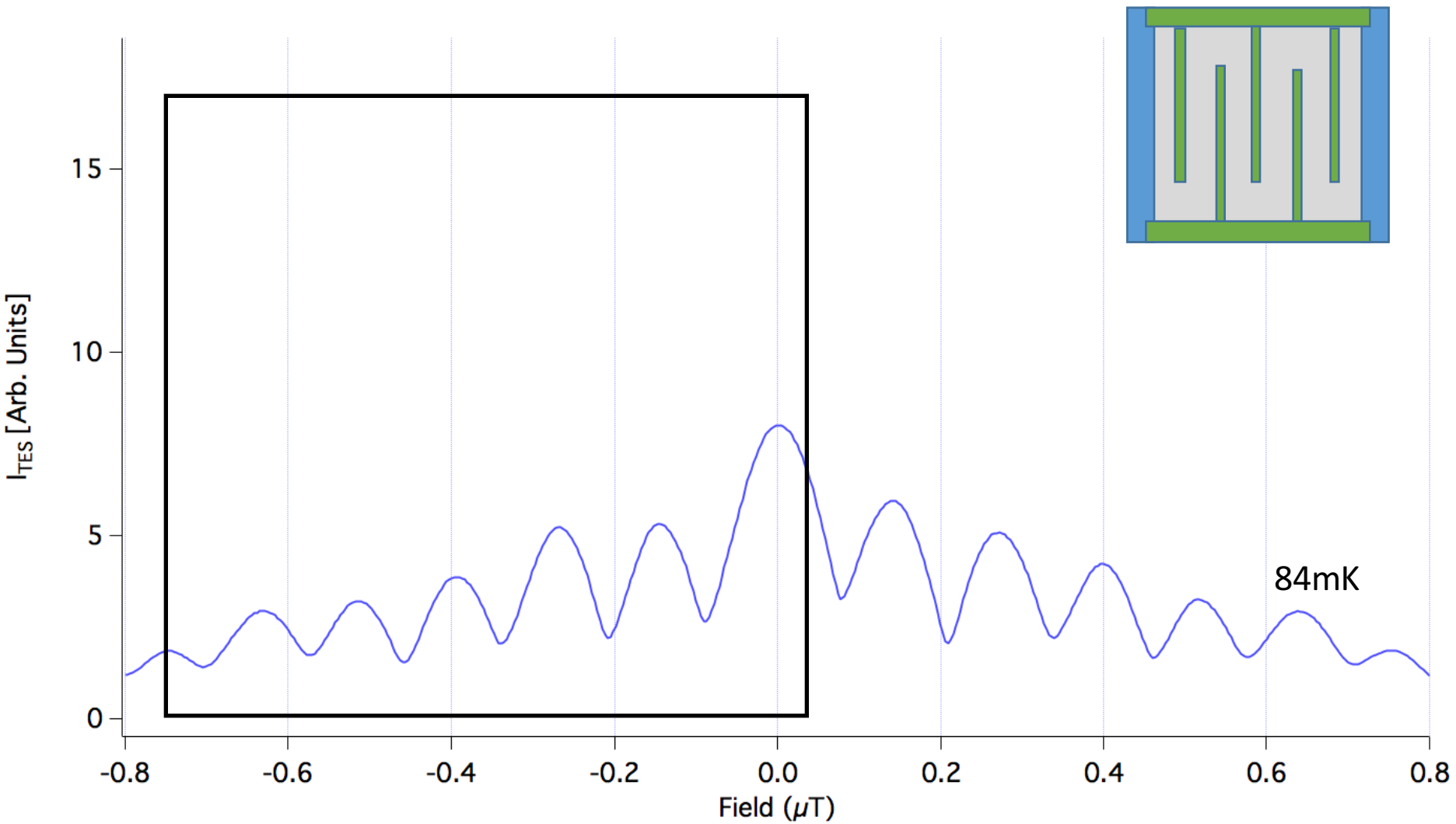
# T dependence of $I_{\text{TES}}(B)$



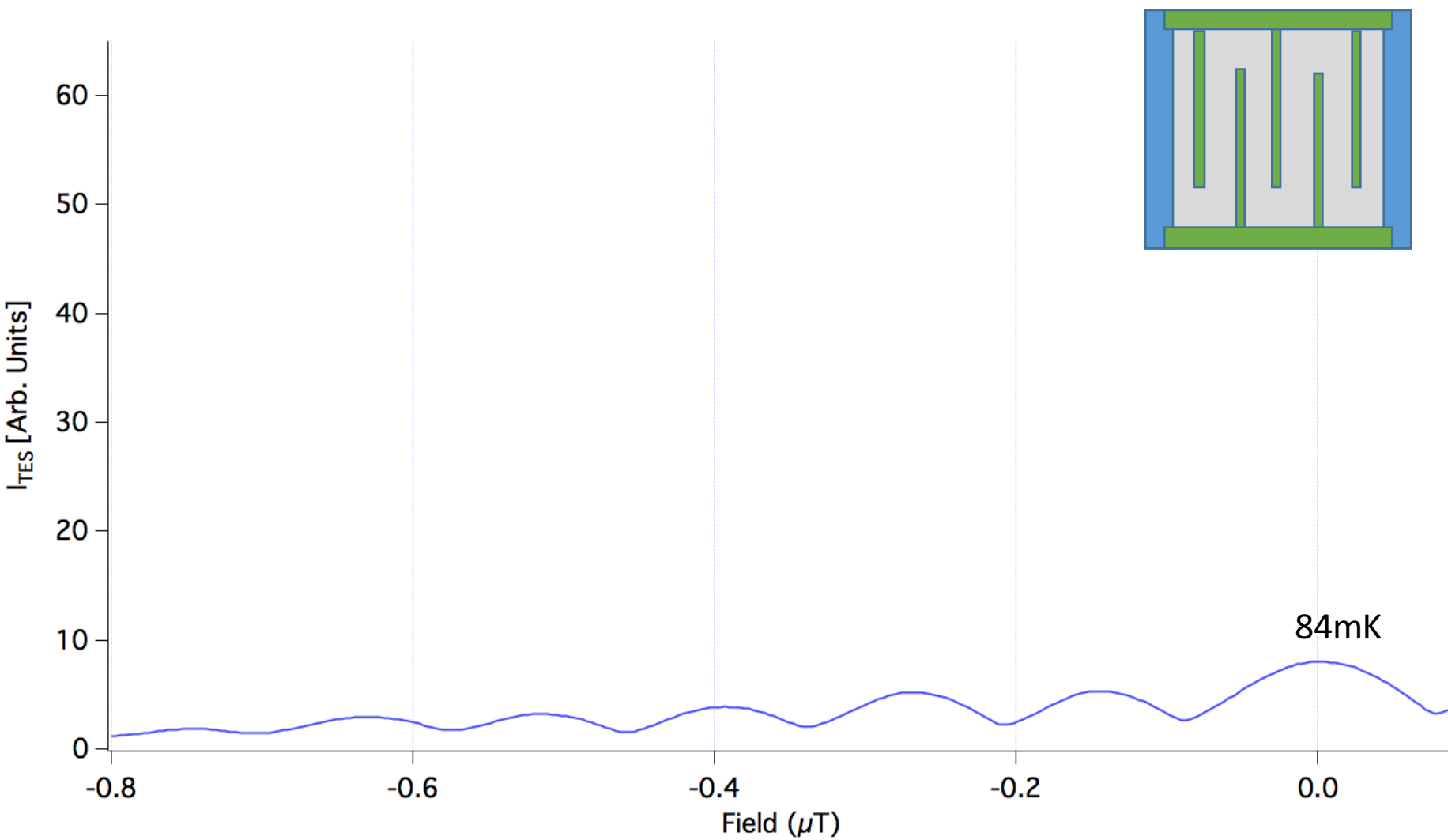
$T_c = 84.5\text{mK}$



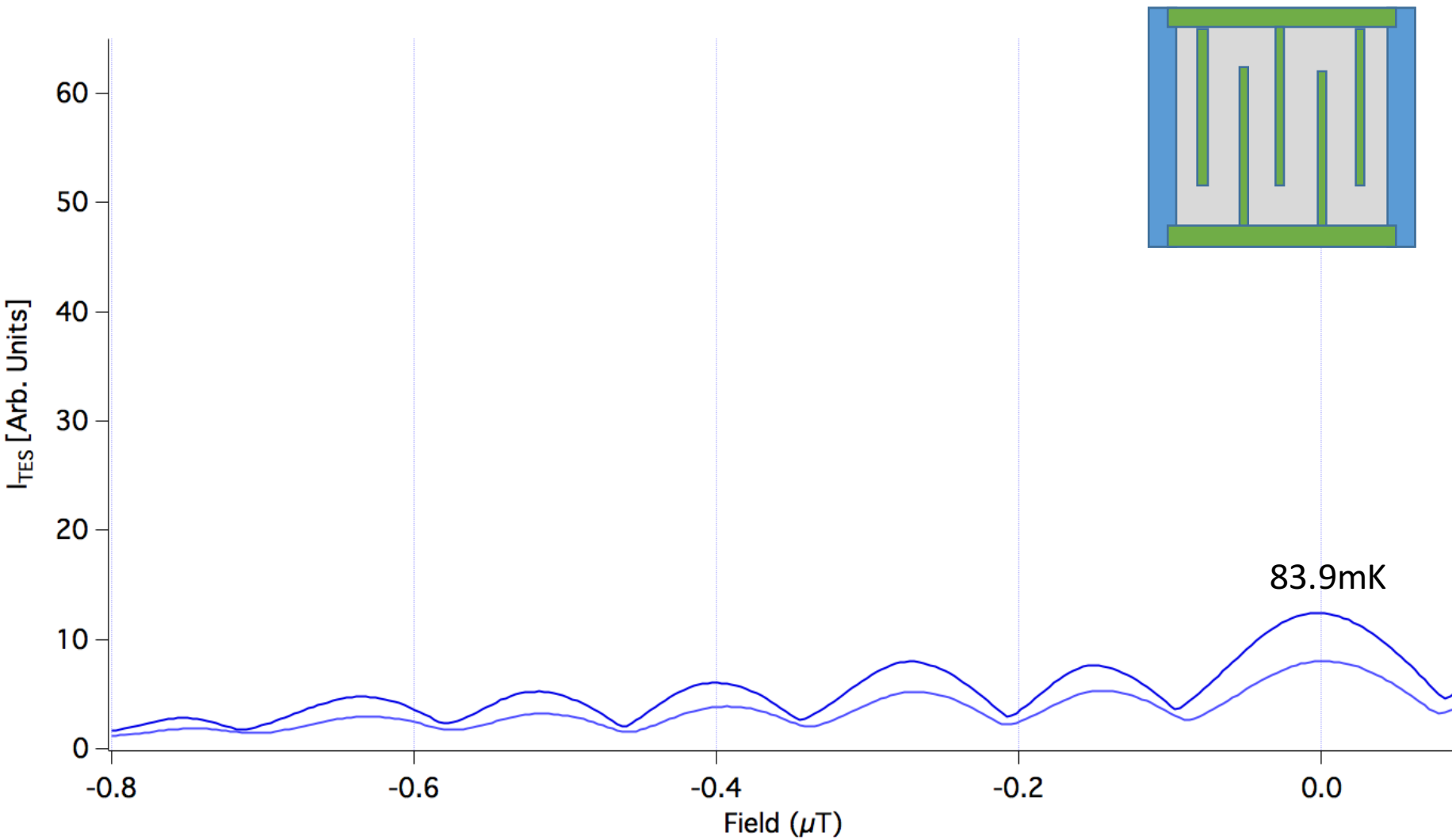
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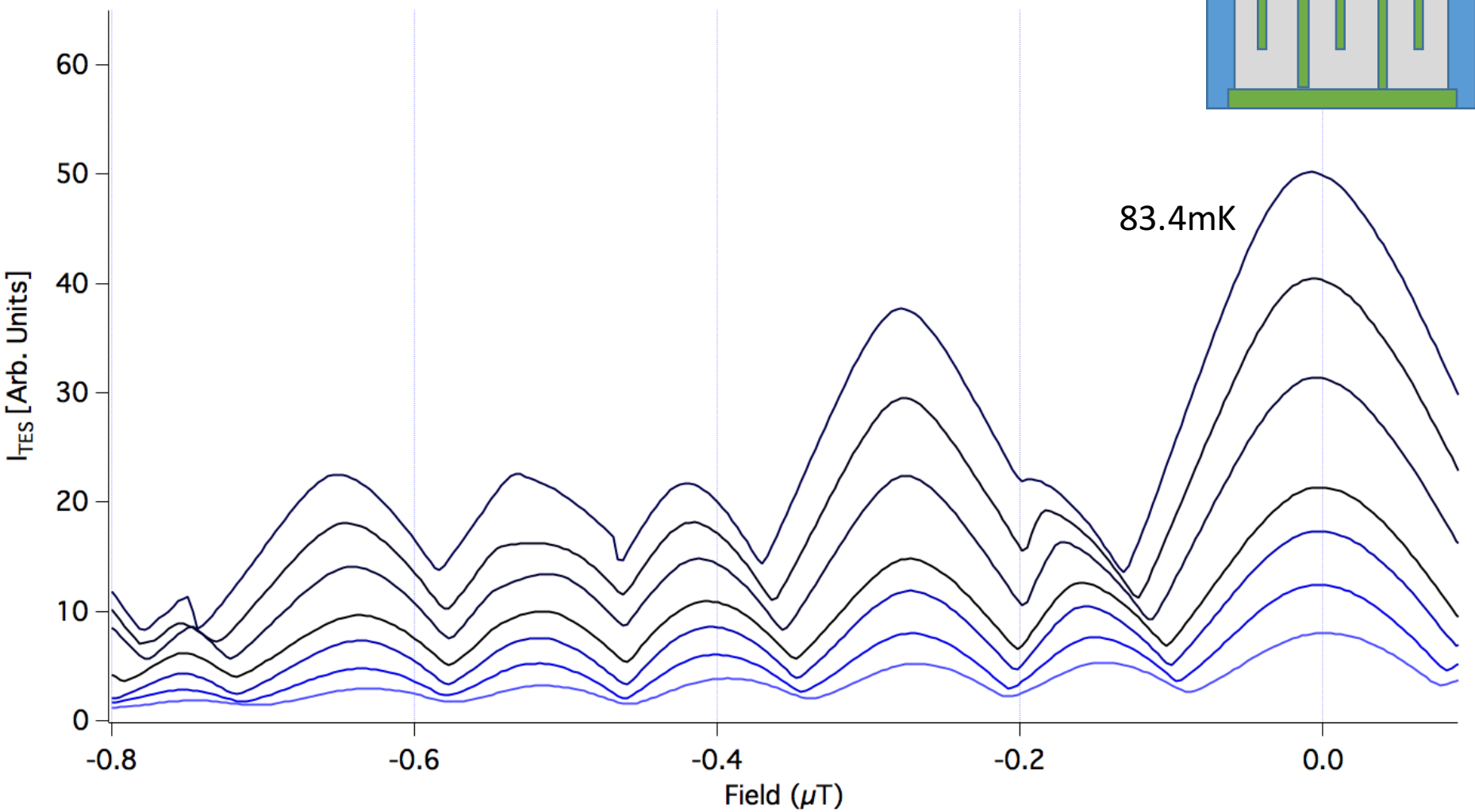
# T dependence of $I_{\text{TES}}(B)$



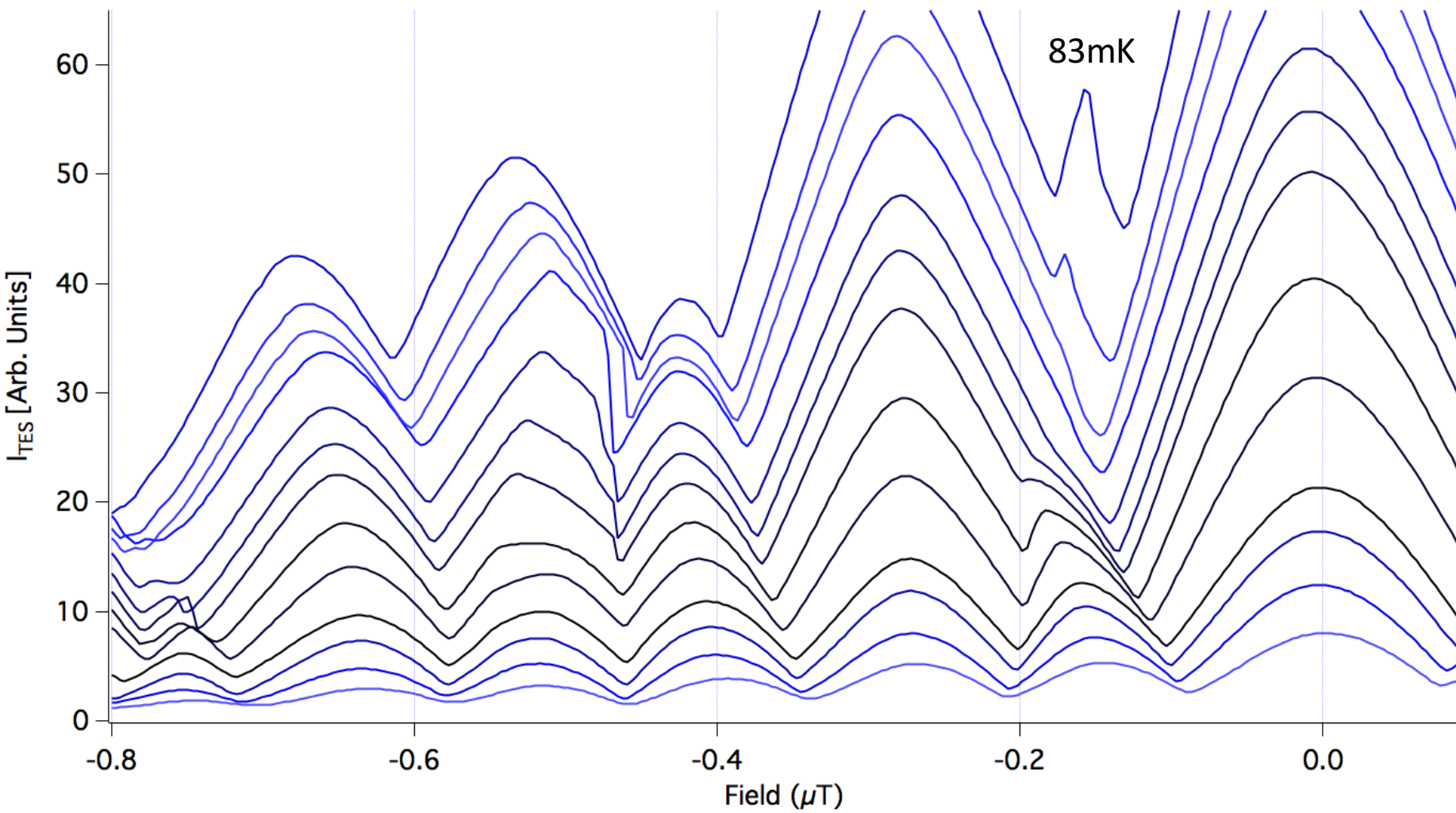
# T dependence of $I_{\text{TES}}(B)$



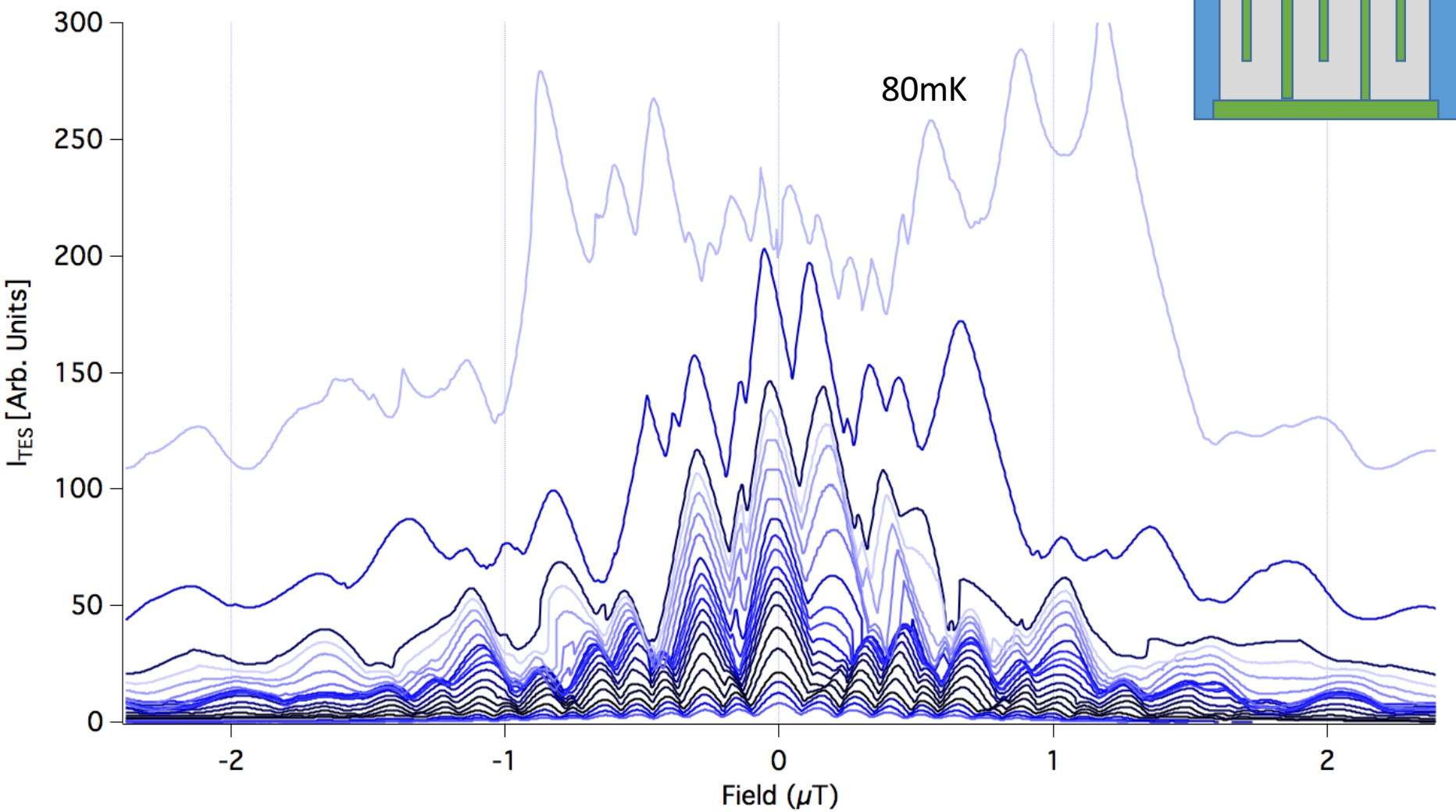
# T dependence of $I_{\text{TES}}(B)$



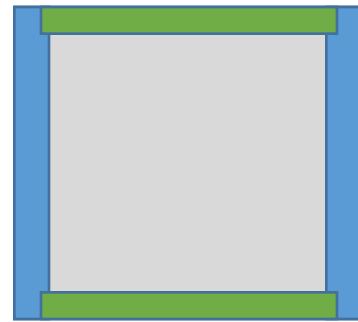
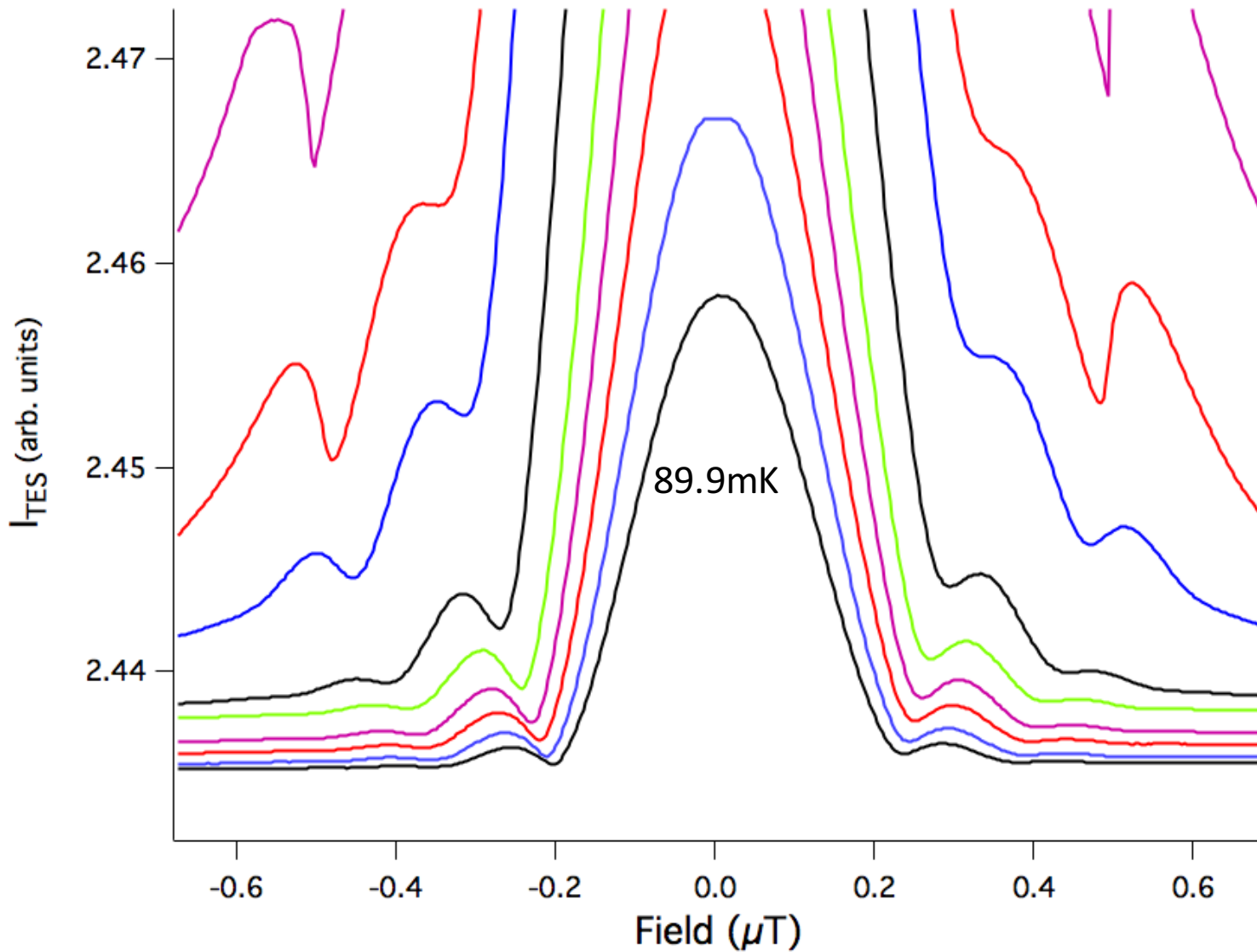
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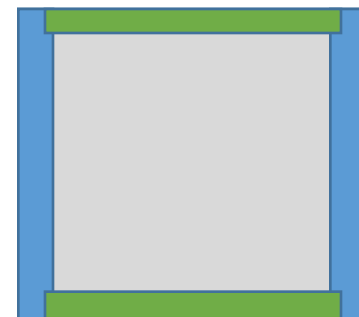
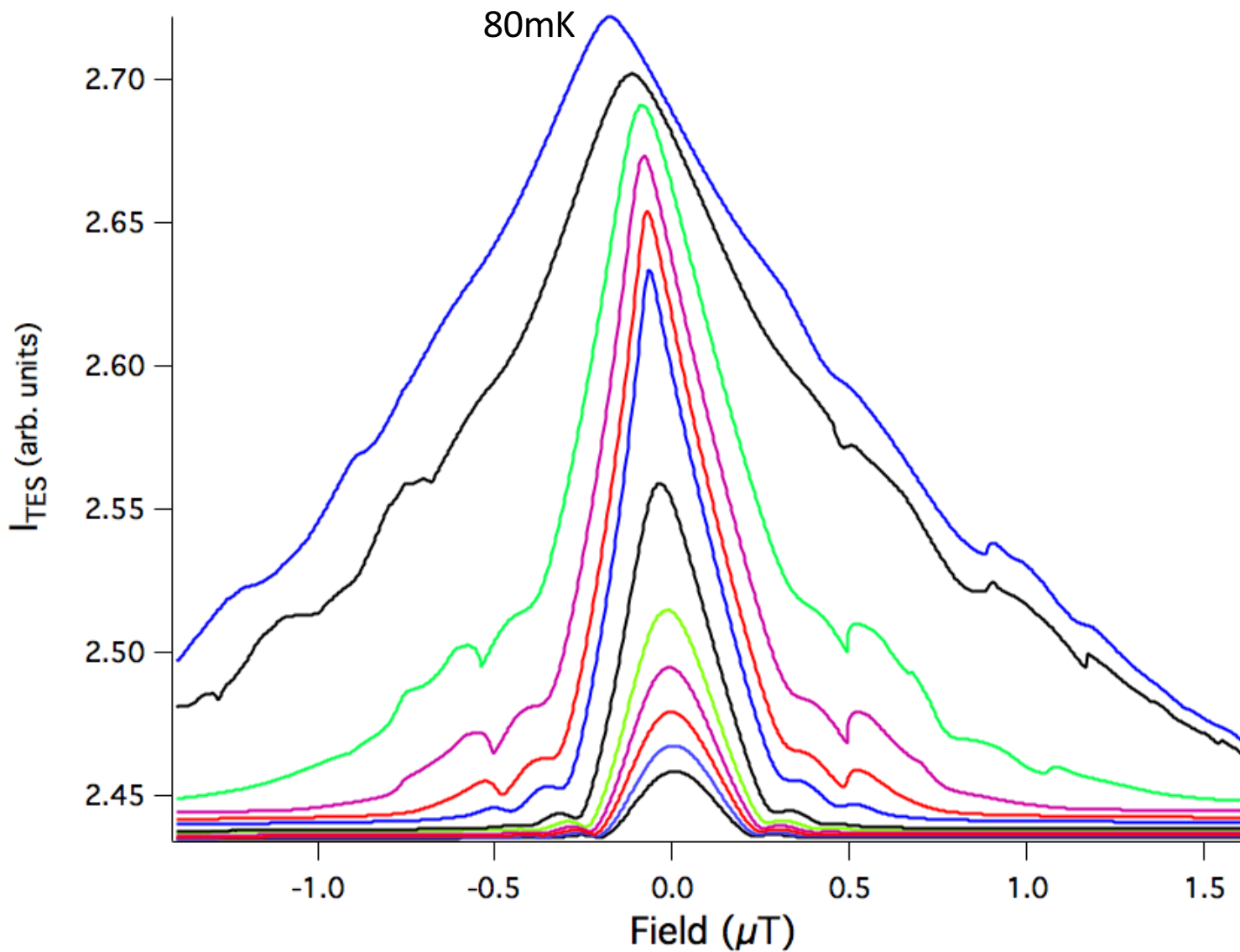


# T dependence of $I_{\text{TES}}(B)$ ----- No Stripes



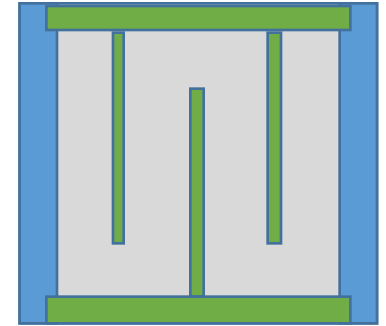
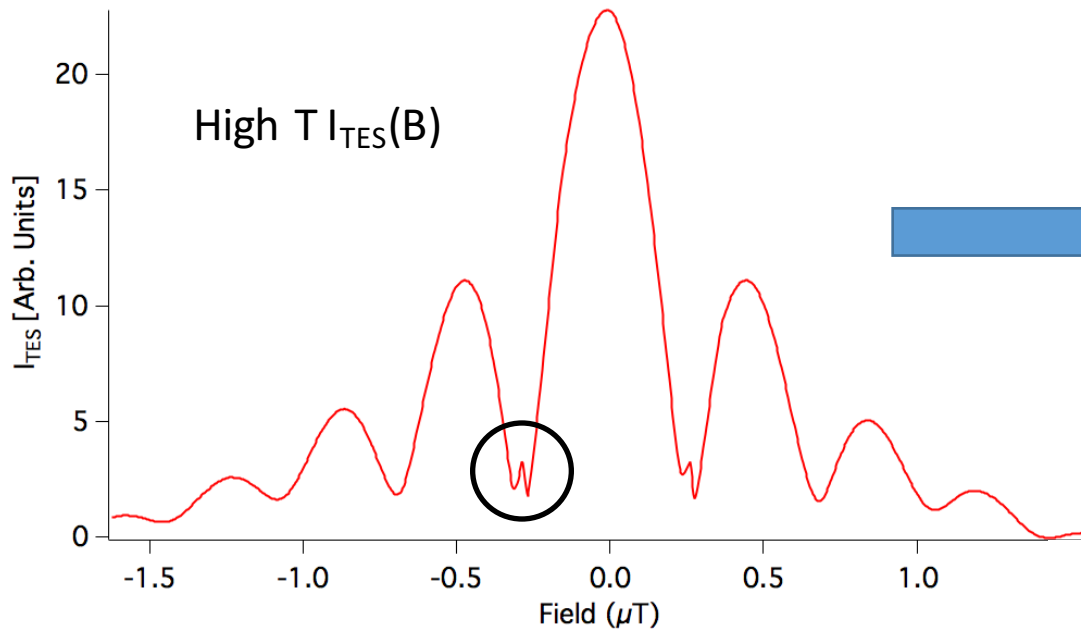
$T_c = 91.6\text{mK}$

# T dependence of $I_{\text{TES}}(B)$ ----- No Stripes



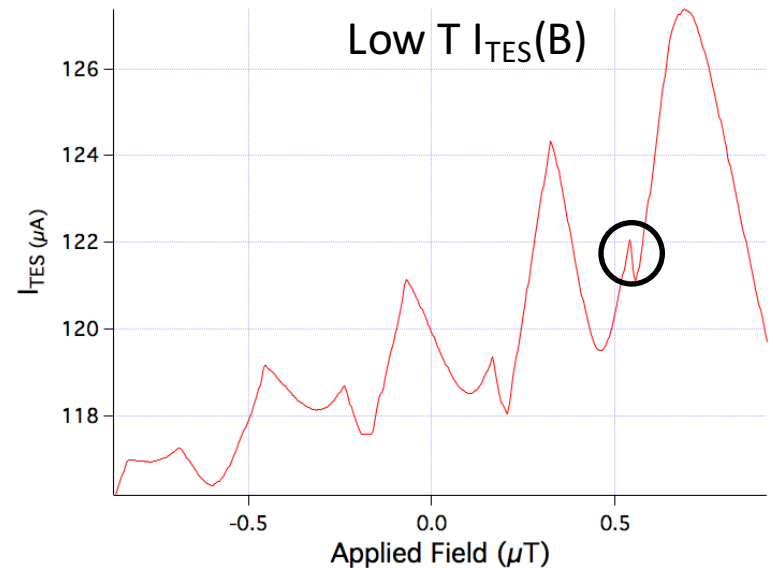


# Three Stripes



Three stripe is an intermediate case.

Oscillatory pattern is not as simple but we still see kinks in the  $I_{TES}(B)$  at low temperature related to the high temperature  $I_c(B)$ .



# Optimizing the transition shape

- Changing the stripe pattern changes the current distribution.
- This changes the  $I_c(B)$  pattern close to  $T_c$  and therefore the  $I_{TES}(B)$  in the transition.
- With no stripes we have a wide region of parameter space without rapid changes in the  $I_{TES}(B)$  ----- transition shapes tend to be smoother.
- Therefore, no stripes may be a route to smoother and more robust transition shapes.

## NOTE:

This is only one type of feature in the transition. There may be others.

Previous data showed hysteric steps -----phase slip lines or other phenomena.

No evidence for these features in these devices but this will have to be investigated further.

# Quantifying performance with no stripes

Measured complex impedance to get  $\alpha$  and  $\beta$  terms of transition.

$$\alpha = \left. \frac{T_0}{R_0} \frac{\partial R}{\partial T} \right|_{I_0} \quad \beta = \left. \frac{I_0}{R_0} \frac{\partial R}{\partial I} \right|_{T_0}$$

Fit to noise spectrum using known parameters for Johnson noise, phonon noise etc.

Quantify the unexplained noise with  $M$ , in the following expression for voltage noise.

$$V_n = \sqrt{4k_b T_0 R (1 + 2\beta)(1 + M^2)}$$

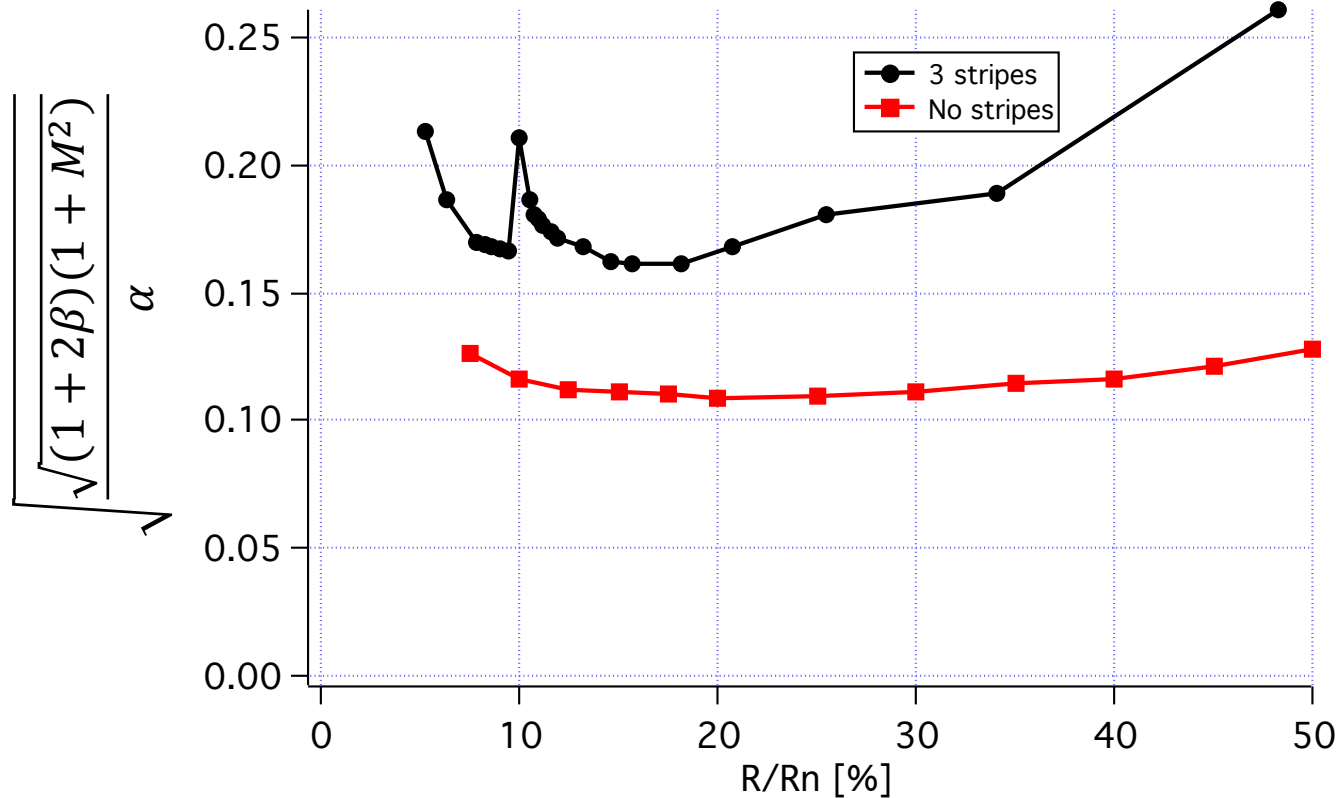
The expected small signal resolution is then given by

$$\Delta E_{FWHM} \approx 2.355 \sqrt{4k_b T_0^2 C \frac{\sqrt{(1 + 2\beta)(1 + M^2)}}{\alpha}}$$

So for devices with fixed  $T_c$  and heat capacity,  $C$ , expected resolution in the small signal limit is proportional to

$$\Delta E_{FWHM} \propto \sqrt{\frac{\sqrt{(1 + 2\beta)(1 + M^2)}}{\alpha}}$$

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This shows that in these no stripe 140μm TES we actually expect a better small signal performance than with 3 stripes

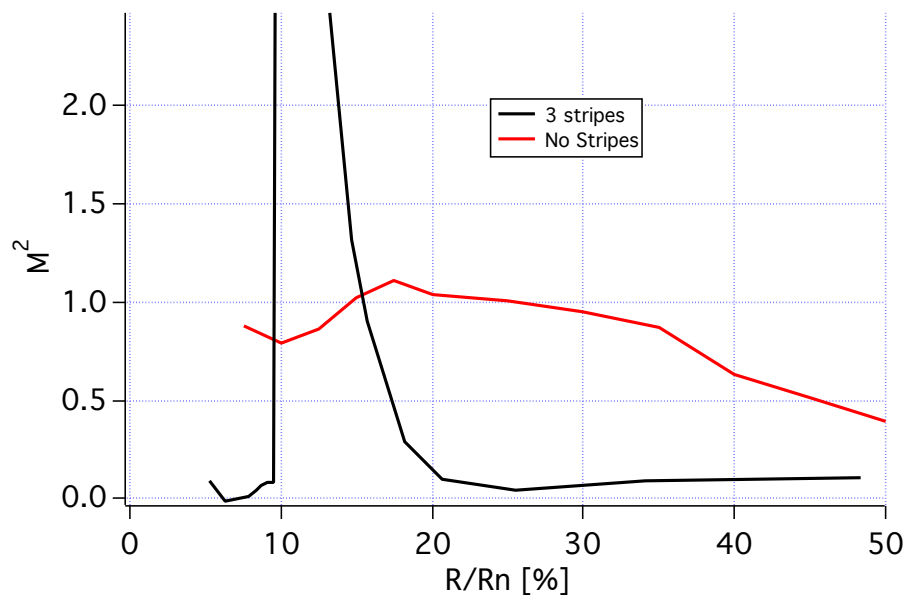
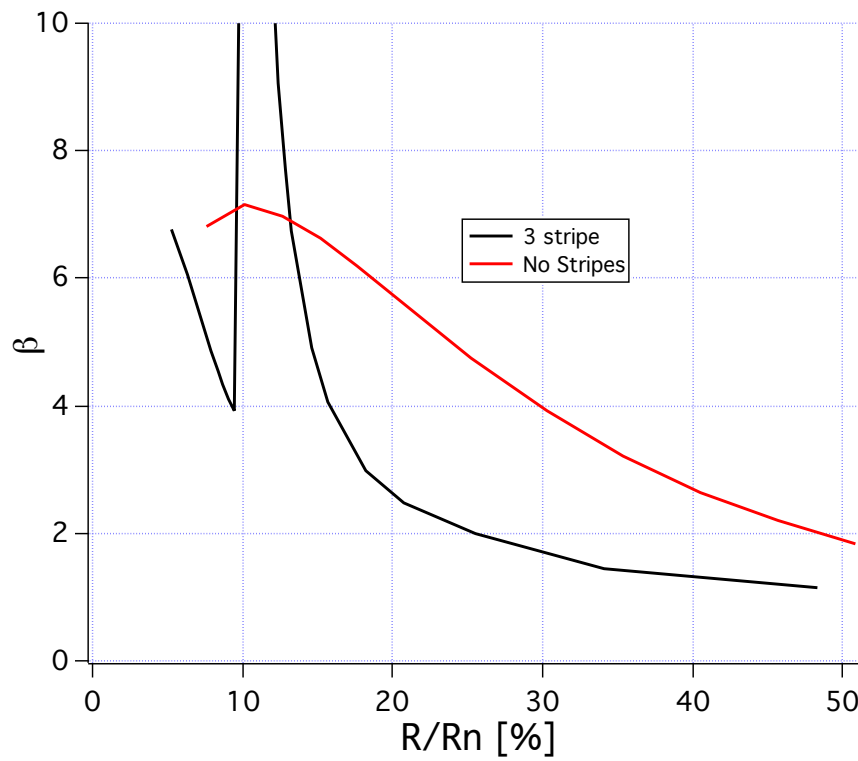
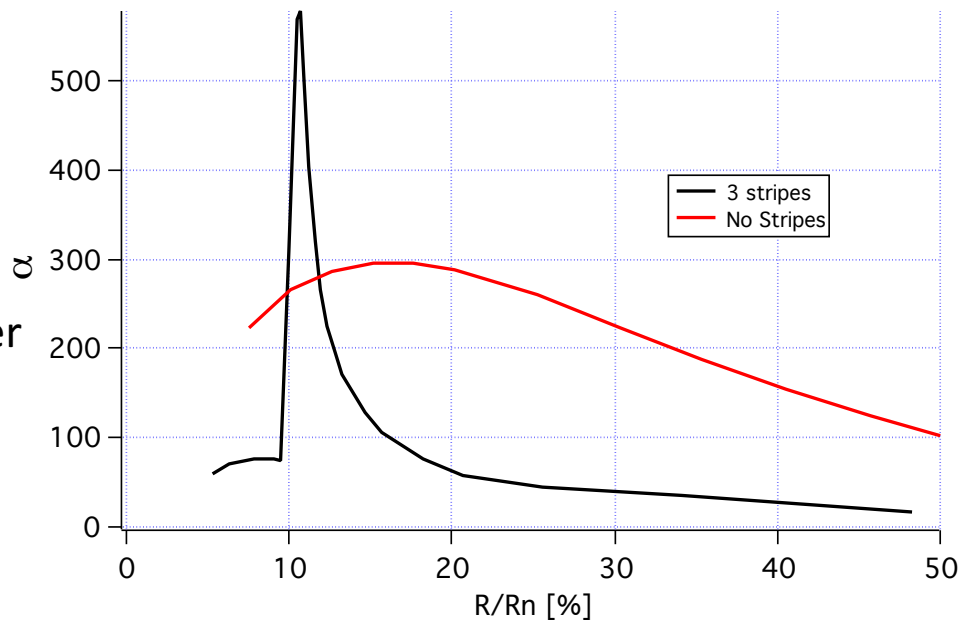
$$\Delta E_{FWHM} \propto \sqrt{\frac{\sqrt{(1+2\beta)(1+M^2)}}{\alpha}}$$

No Kink with no stripes

Away from the kink,  $\alpha$ ,  $\beta$ , and  $M^2$  are all larger with no stripes

Unexplained noise larger with no stripes, as expected.

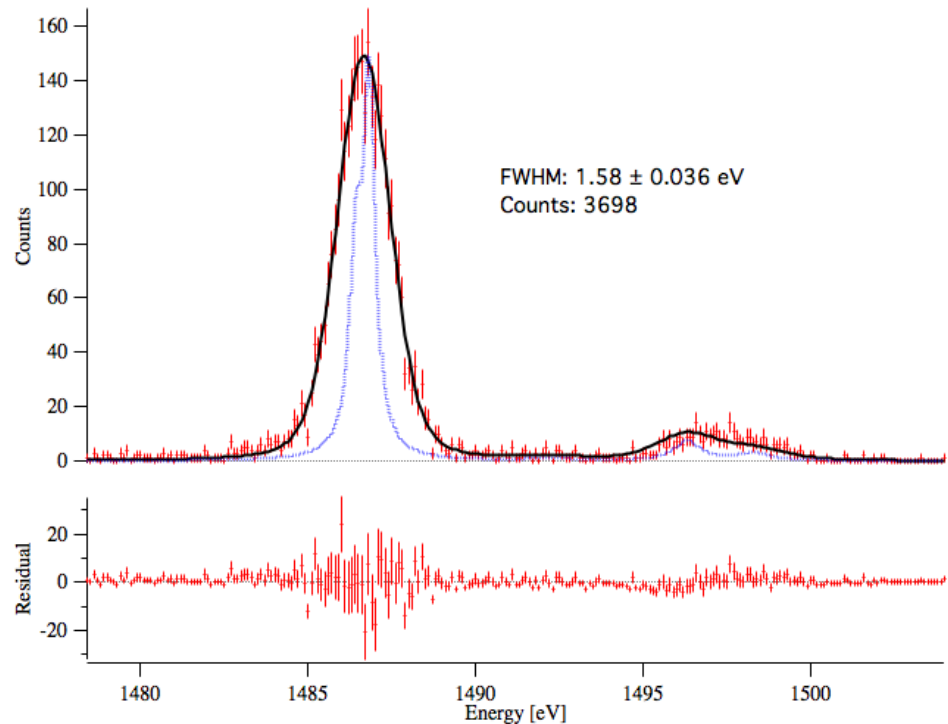
Note: 250um devices  $M^2 \sim 40$  was measured for similar  $\alpha$  and  $\beta$  Jethava et al. AIP Conf. Proc. 1185, 31 (2009);



# Quantifying performance with no stripes

140um no stripe device -----  
analysis predicts a small signal  
resolution of 1.5 eV

Measured spectral resolution of  
1.6eV at the 1.5KeV Al Ka line



Optimizing for higher energy x-rays will require a larger heat capacity than in the pixels tested.

Expect slight degradation of energy resolution with the larger C but our analysis predicts resolutions of around 1.8eV at 6 KeV.

## **Conclusion:**

In these small no stripe devices we may be able to get good spectral resolution, and smooth transitions

# Future work

General trends reproducible on individual pixels from different chips and wafers and in sizes ranging from 140 – 50  $\mu\text{m}$ .

Need to test full large arrays of no stripe devices to fully test robustness across parameter space

## **Outstanding question:**

Why is the unexplained noise in these devices with no stripes smaller than seen previously?

- The size of TES and the nature of the metal banks is likely important.
- But are there also other factors that are different now?
- For example:
  - Interface quality between layers
  - $T_c$
  - Thermal conductance
- As we explore the parameter space with the new arrays we may get some answers.